Assessing Impacts of Rangeland Management and Afforestation of Rangelands on Net Greenhouse Gas Emissions
A Scoping Study for Shasta County (CA)

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APPLIED GEOSOLUTIONS

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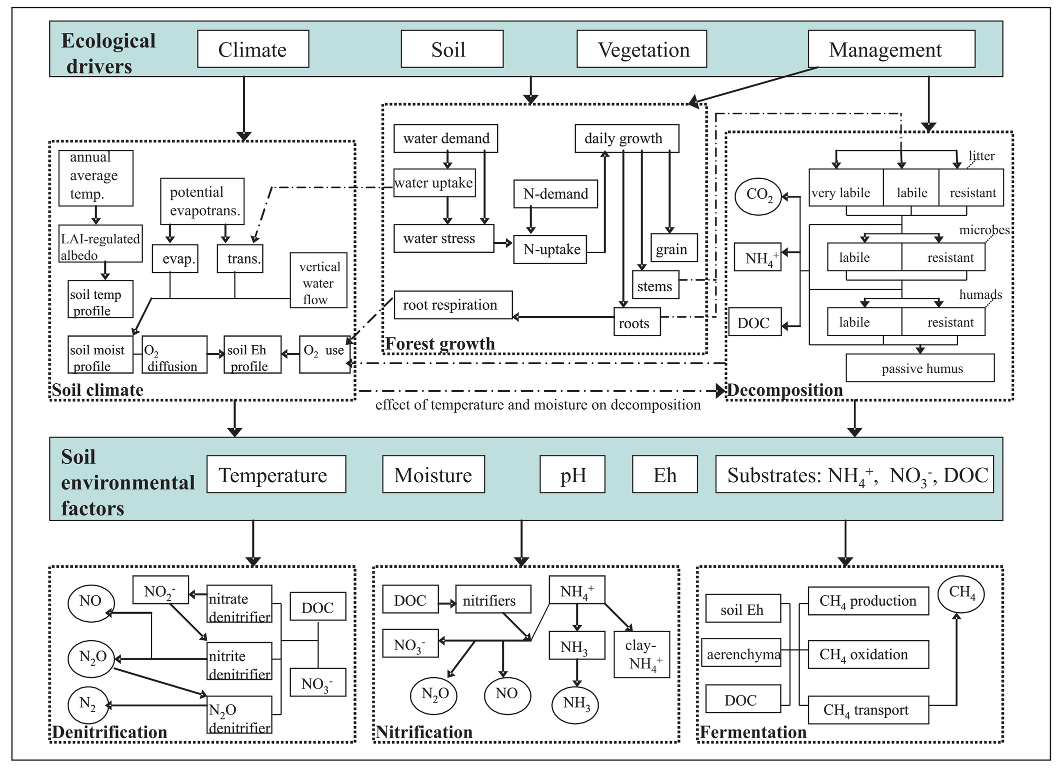
Forest-DNDC Model

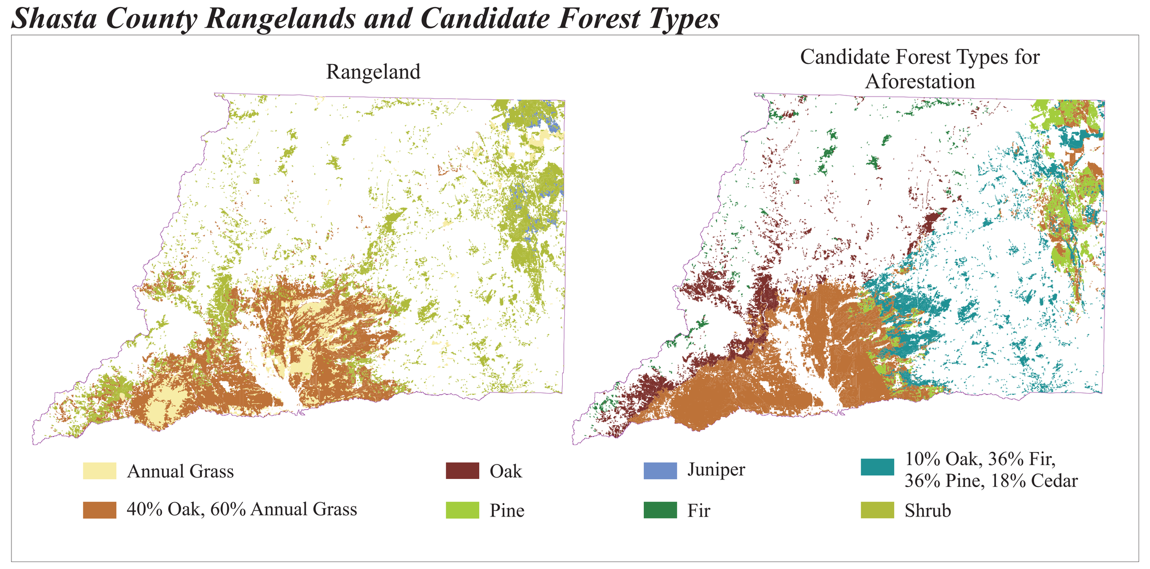


DNDC, or Denitrification-Decomposition, is a process-based biogeochemical model for predicting soil C dynamics and trace gas emissions. The basic version of DNDC has been linked to crop/grass growth sub-models to simulate C and N biogeochemistry for agricultural (including grass or pasture) land. In addition, the core of DNDC has been integrated with a forest physiology model, PnET, to serve forest biogeochemistry studies. In this project, we linked the agricultural DNDC with Forest-DNDC to track soil C dynamics and trace gas emissions during the transition from rangeland to forests.

Background and Model Development

Spatially explicit GIS data on soils, climate, land cover and forest/rangeland management were acquired for Shasta County for input into the Forest-DNDC model. In addition, field samples and observed data were used for validation and calibration of the model.

Shasta County Rangelands and Candidate Forest Types



Rangeland distribution in Shasta County was derived from the CDF-FRAP Multi-source land-cover map using the WHR landcover classification system. DNDC rangeland and candidate forest type designations were identified for each of the polygons in the DNDC basemap coverage to build the input files for the rangeland and forest DNDC analysis.

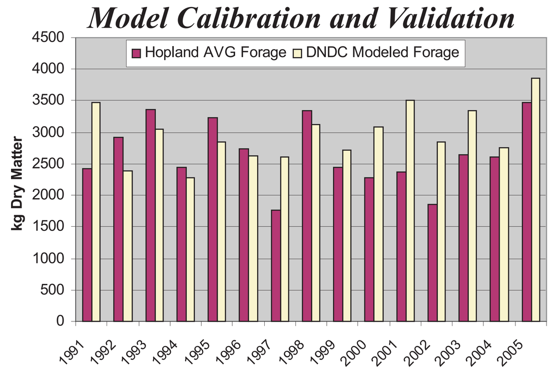
Forest-DNDC Input Parameters

Parameter	Unit
Climate - daily maxmum and minimum air temperature - daily precipitation - photosynthesis actively radiation (PAR) - atmospheric N deposition	 °C cm/day umole/m2/s ppm
Soil - organic C content at litter layer - organic C content at top of mineral soil - bulk density of mineral soil - pH at litter layer - pH at mineral soil - texture of mineral soil - clay fraction in mineral soil - stone fraction of the soil	 Kg C/ha Kg C/kg soil G/cm3
Vegetation - forest type - forest age	 Year

The table to the left lists the required input parameters for Forest-DNDC. For this analysis, we simulated afforestation using our generic model for Pine, Fir and Oak.

Fourteen years of average forage production at the Hopland Research Station site was obtained and compared with DNDC model estimates (figure to right). While the field data exhibited greater inter-annual variability, the magnitude of the DNDC modeled forage production estimates were comparable to the field data.

Model Calibration and Validation



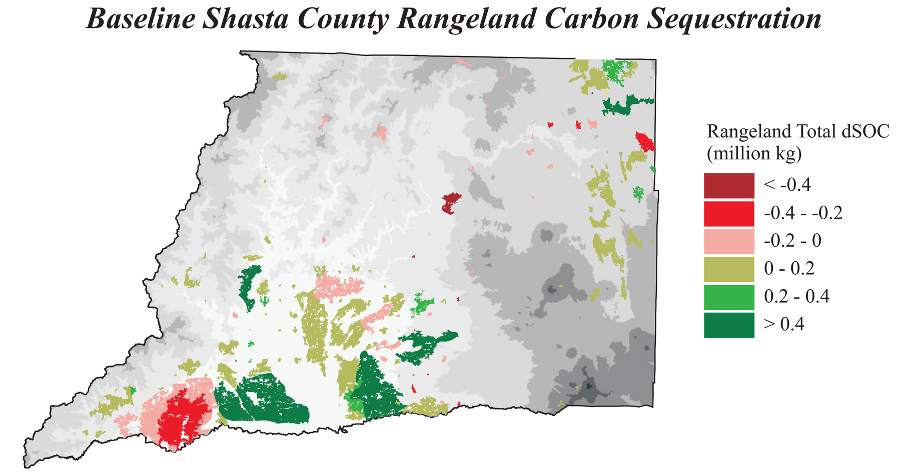
Overview: This poster presents a geospatial modeling framework for quantifying net trace gas emissions and soil carbon sequestration as part of a study to assess potential carbon supply curves for afforestation of rangelands in Shasta County. This framework utilizes spatially explicit GIS data on soils, climate, potential forest type and current rangeland types and forest/rangeland management combined with two soil biogeochemical process models, DNDC and Forest-DNDC. Our objective was to demonstrate our modeling framework to map and assess the spatial and temporal distribution of trace gas emissions and soil carbon dynamics for Shasta County under current baseline rangelands and for the first 50 years following afforestation.

Model Results

Results from the Forest-DNDC analysis for Shasta County include: a) predicted baseline carbon dynamics and greenhouse gas emissions for existing rangelands in Shasta County, b) estimated impact of alternative rangeland management strategies (various grazing intensities) on soil carbon stocks and trace gas emissions, and c) predicted impact of reforestation on soil carbon dynamics and greenhouse gas emissions across Shasta County.

Baseline Carbon Dynamics and GHG Emissions

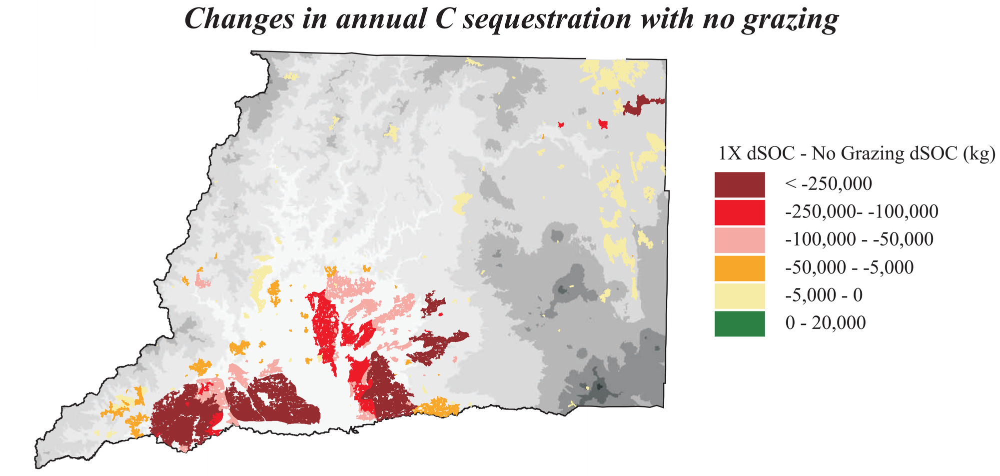
Baseline Shasta County Rangeland Carbon Sequestration



Based on the Forest-DNDC model parameters, we estimated soil carbon dynamics and trace gas emissions (Nitrous Oxide N2O and Methane -CH4) for Blue Oak Woodlands, annual grasslands and our generic shrub classes. The regional patterns of total carbon sequestration shown in the figure above indicate that the annual grassland in the Southwest region of the county are losing carbon, where as most of the other regions of rangelands are sequestering carbon. Annual carbon sequestration of rangeland area is 5,640 metric tons of carbon per year, with all rangelands sequestering on average 29 kg C/ha/yr.

Impacts of Grazing Intensity on Rangeland

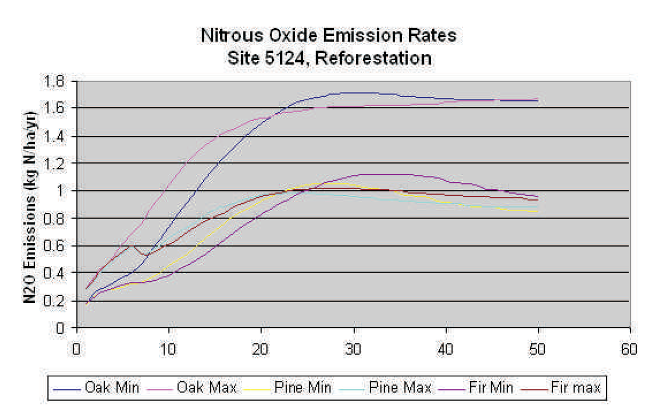
Changes in annual C sequestration with no grazing



The impact of grazing intensity on soil carbon dynamics depends on site quality (initial soil organic carbon content). For sites with higher initial SOC, increased grazing intensity will decrease the rate of carbon sequestration. In general, the DNDC model indicates that in the absence of grazing, rangelands of Shasta County would be sequestering ~50 kg C/ha/yr, an increase of 21 kg C/ha/yr over nominal grazing intensity. The figure above presents the patterns of net carbon sequestration by shifting to no grazing of annual grassland.

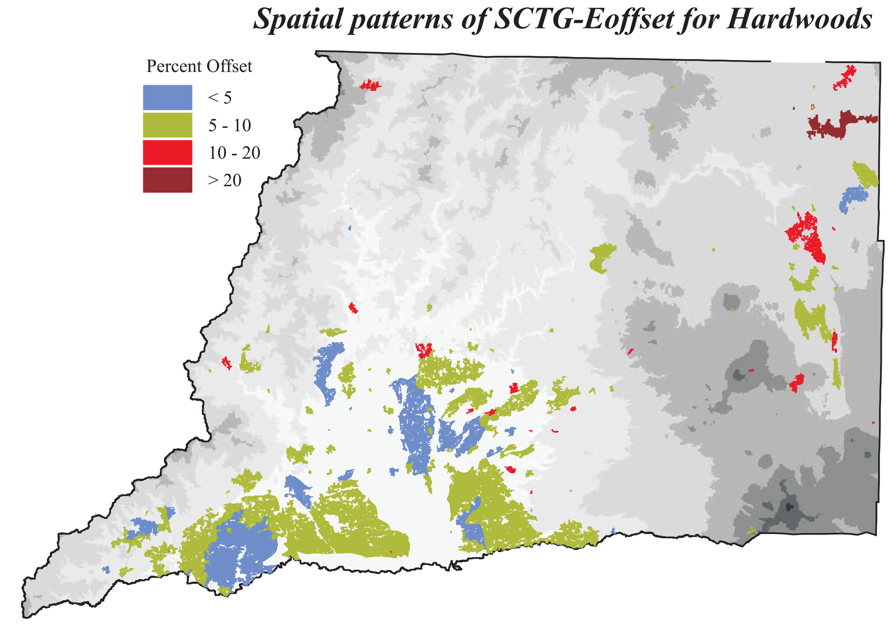
Reforestation Carbon and GHG Emission Dynamics

Based on our model results we compiled a complete greenhouse gas balance for 50 years following afforestation and compared it with our baseline model results to map changes in net GHG balance. To do this, we compared the magnitude of the carbon sink due to tree biomass and forest floor carbon accumulation with the net carbon source from the cumulative loss in soil carbon and trace gas emissions and baseline rangeland dynamics over the 50 year period. Our results indicate that in general full accounting adjusted carbon sequestration potential by less than 10%.



Changes in the carbon stock of trees, soil and forest floor litter during afforestation can impact trace gas emissions. This is illustrated in the model simulations above which indicate Oak stands would have approximately double the N2O emission rates after 40 years of stand development.

Spatial patterns of SCTG-Eoffset for Hardwoods



We also examined the true net GHG benefits by accounting for not only SCTG-E effects, but also the net GHG balance of the rangelands prior to afforestation utilizing the following equation:

Net GHGafforestation = C-Stock + SCTG-E + NetGHGrange

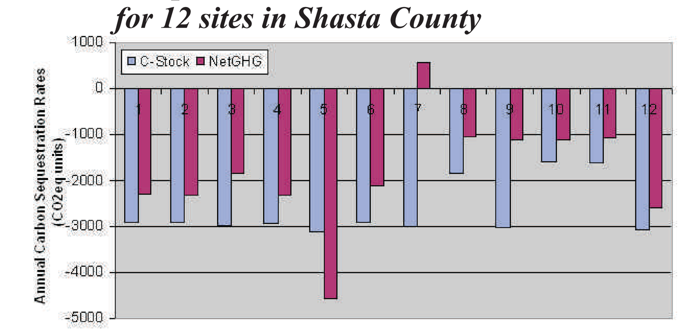
In general, NetGHGafforestation estimates are lower than C-Stock estimates, due to soil carbon loss during afforestation and removal of the net carbon sink of rangelands.

The impact of soil carbon losses and trace gas emissions (referred to as SCTG-E) on the net GHG balance are calculated as the percent offset of emissions relative to carbon sequestered in woody biomass and forest floor (C-Stock):

SCTG-Eoffset = SCTG-E (CO2eq) / C-Stock (CO2eq)

SCTG-Eoffset varies spatially across forest types driven by difference in forest productivity and soil conditions. Sites with higher SCTG-Eoffset were characterized by low forest productivity. Over 90% of the sites had SCTG-Eoffset values less than 12%. Areas with high SCTG-E had high soil organic carbon (SOC) content prior to afforestation. Areas with higher SOC typically have larger losses of soil carbon during forest establishment, will oxidize more methane and will have higher nitrous oxide emissions.

Comparison C-Stock and NetGHG accounting for 12 sites in Shasta County

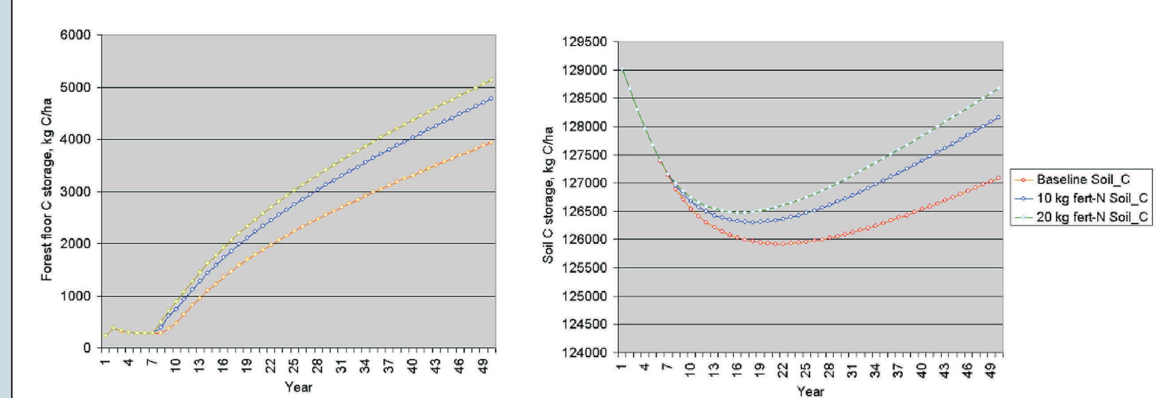


Additional Research Needs

Several additional issues related to afforestation of rangelands in Shasta County have been examined including the potential benefits of using fertilizer to enhance forest productivity and net carbon sequestration as well as the impacts of rangeland afforestation on local hydrology.

Impacts of Fertilization

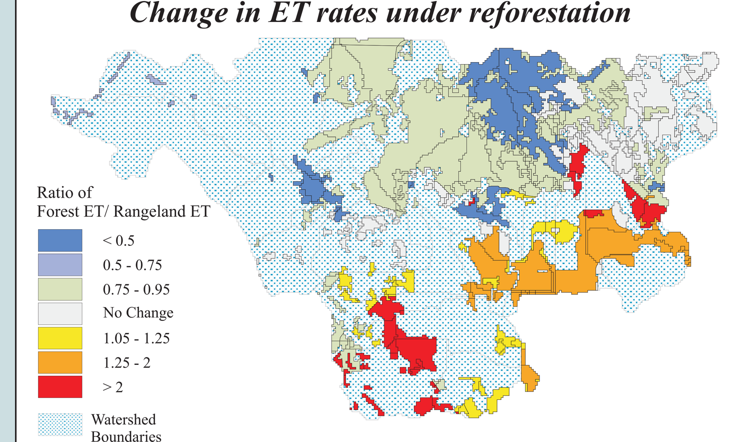
A sensitivity analysis was run on an upland site in Shasta County to examine the impacts of fertilization on C and N dynamics during the afforestation process. Results indicate that fertilization increased the forest productivity and C storage in the forest biomass and forest floor pools (below left). C in the soil mineral pool slightly decreased due to enhanced decomposition with higher availability of free N (below right). Fertilization increased N2O emissions slightly with little change in CH4 oxidation. Based on this site result, it appears fertilization may ameliorate differences in C-Stock and net GHG sequestration by enhancing productivity and reducing soil carbon losses.



Changes in Hydrology

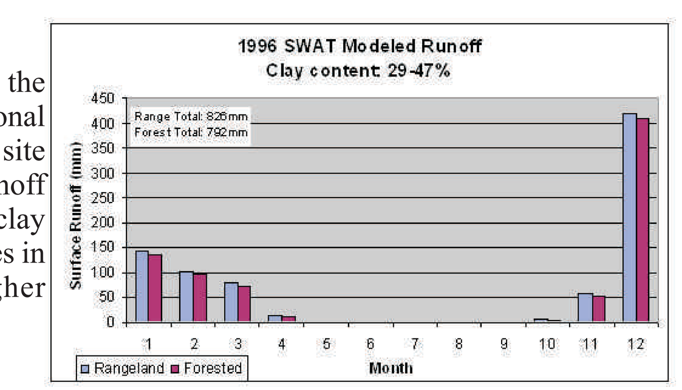
The potential impact of reforestation on evapo-transpiration and surface runoff were assessed for a drainage basin in northeastern Shasta County.

Change in ET rates under reforestation



The SWAT model was employed to run initial water budget analyses under current rangeland conditions and future reforestation scenario for selected sub-basins in Shasta County. The figure to the left compares evapotranspiration (ET) rates for current rangeland and a full afforestation scenario represented as the ratio of reforested ET to current rangeland ET.

The figure to the right illustrates the impacts of reforestation on seasonal runoff for a high clay content site showing a decrease in surface runoff following reforestation. Lower clay content sites did not exhibit decreases in runoff presumably due to higher infiltration rates offsetting ET.



Acknowledgements

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